Harps in high radiation environments

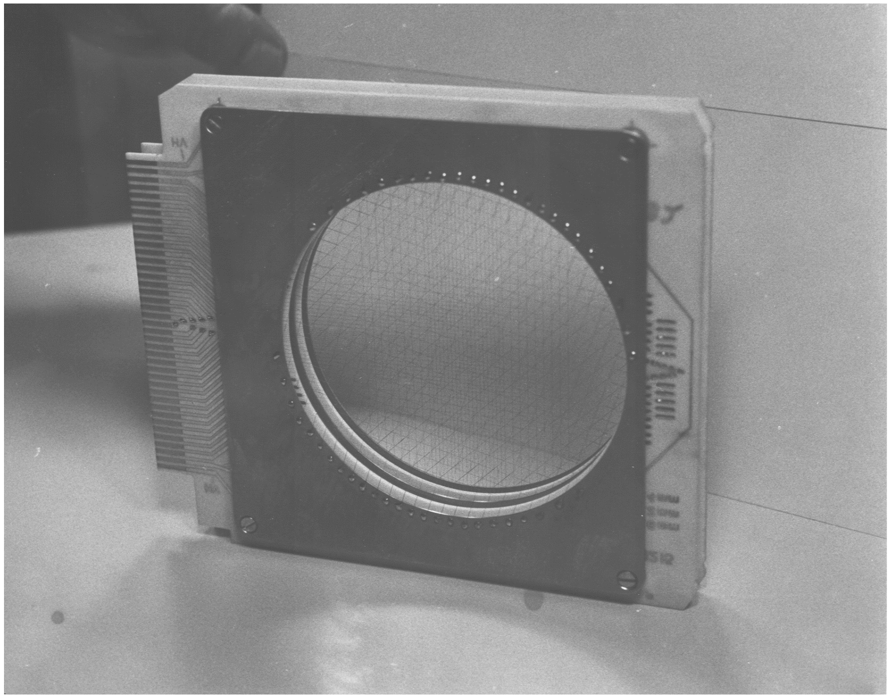
11th ICFA International Mini-Workshop on Diagnostics for High-Intensity Hadron Machines

October 21-23, 2002

by Mike Plum

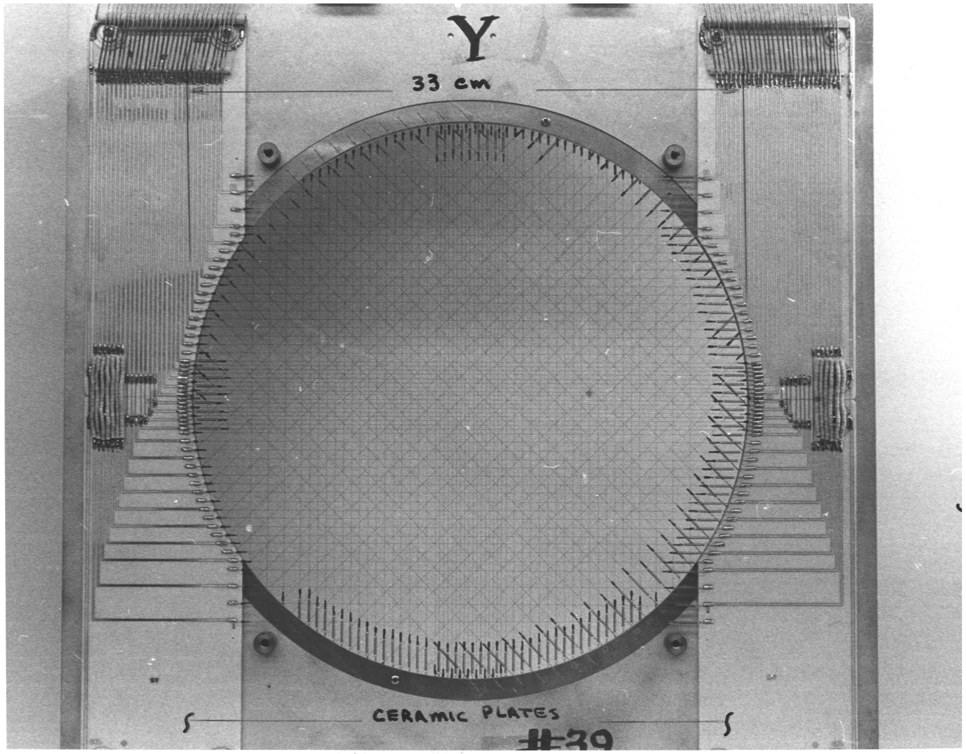
Overview of LANSCE profile measurements

- Area A harps – 10 cm
  - 1 MW average beam power.
  - 30 ea. 0.032 mm carbon wires.
  - Wire spacing dense in middle and sparse at ends. 0.6, 1.2, and 2.4 mm spacing.
  - HV - signal - HV - signal - HV arrangement.
  - Inserted with air actuators.



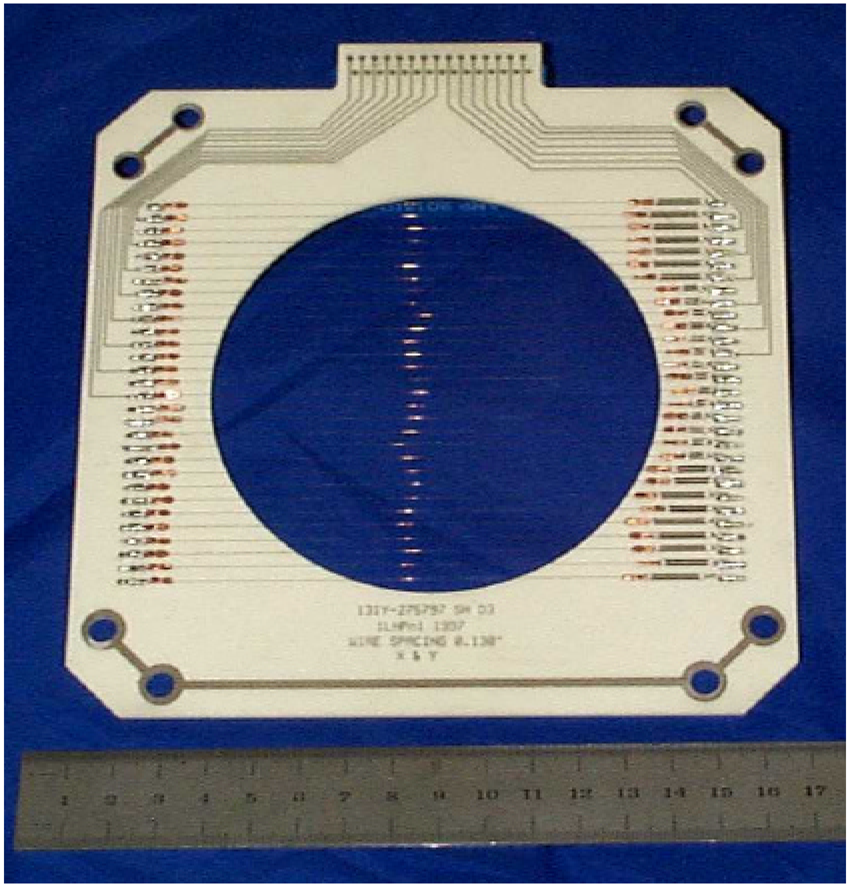
Overview of LANSCE profile measurements

- Area A harps – 33 cm
  - 1 MW average beam power.
  - 58 ea. 0.10 mm SiC wires.
  - Wire spacing dense in middle and sparse at ends. 2.5, 5, and 10 mm spacing.
  - HV - signal - HV - signal - HV arrangement.
  - Springs at one end of each wire.
  - Always in beam.



Overview of LANSCE profile measurements

- LANSCE target harp – 10 cm
  - 80 kW average beam power.
  - 30 ea. 0.10 mm SiC wires.
  - Uniform spacing.
  - HV - signal - HV - signal - HV arrangement.
  - Springs at one end of each wire.
  - Always in beam.



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Harp Lifetimes

Harp	mA-hours	Avg. / peak beam density	Comments
1AHP02 (10 cm,C)	100 (1991) 100 (1992) 100 (1993) 100 (1994)	160 μA/mm^2 1.6 mA/mm^2 (σ = 1 mm)	1 - 5 x 10^{-3} Torr.
2AHP03 (10 cm,C)	100 (1991) 300 (1994)	3.3 μA/mm^2 33 μA/mm^2 (σ = 7 mm)	1 - 5 x 10^{-3} Torr. One year a few 10^{-2} Torr.
6AHP01 (33 cm,SiC)	2090 (1991) 2575 (1994) 4595 (1996) 1250[a] (1997)	0.6 μA/mm^2 6.0 μA/mm^2 (σ = 16 mm)	1 - 5 x 10^{-3} Torr. [a](vacuum accident)
1LHP01 (10 cm, SiC)	380 (1998) 110 (2002)	0.07 μA/mm^2 14000 μA/mm^2 (σ = 15 mm)	1 x 10^{-6} Torr.

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Harp PC boards

- Use ceramic boards.
- Use platinum traces 0.018 mm thick on the ceramic boards to avoid mixed waste issues (silver would be a mixed waste).
- Use lead-free solder to avoid mixed waste issues.
- Area A 10-cm harp actuators are placed far (6.7 m) away from the beam line.
- At detector-end of 10-cm harp cable plant the edge connectors get brittle over time, which makes it difficult to change a harp card.

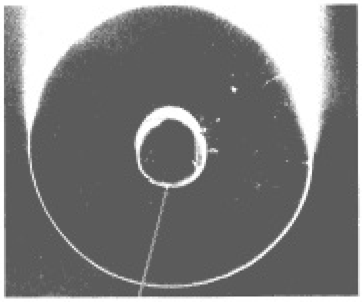
Harp signal wires

- Our best high-intensity wires are 0.1-mm SiC and 0.032-mm C.
- SEM coeff. of SiC wire may change with time due to outer layer of carbon burning off to expose SiC. At first C would only burn off in the center, meaning different SEM response to different parts of the beam.
- SEM coeff. changes anyway, by up to a factor of two, as material is exposed to beam.
- It is now possible to buy SiC wires without the carbon coating (e.g. Goodfellow #SI675910).
- My personal philosophy on harp and wire scanner wires: Use metal wires where you can. Use C and SiC wires only where metal wires would cause problems.

LOW COST SILICON CARBIDE FILAMENTS — For Metal Matrix Applications

Avco is developing a low cost Silicon Carbide filament for the reinforcement of metal matrix composites. The Silicon Carbide filament is potentially very low cost and is compatible with high temperature processing in aluminum and titanium.

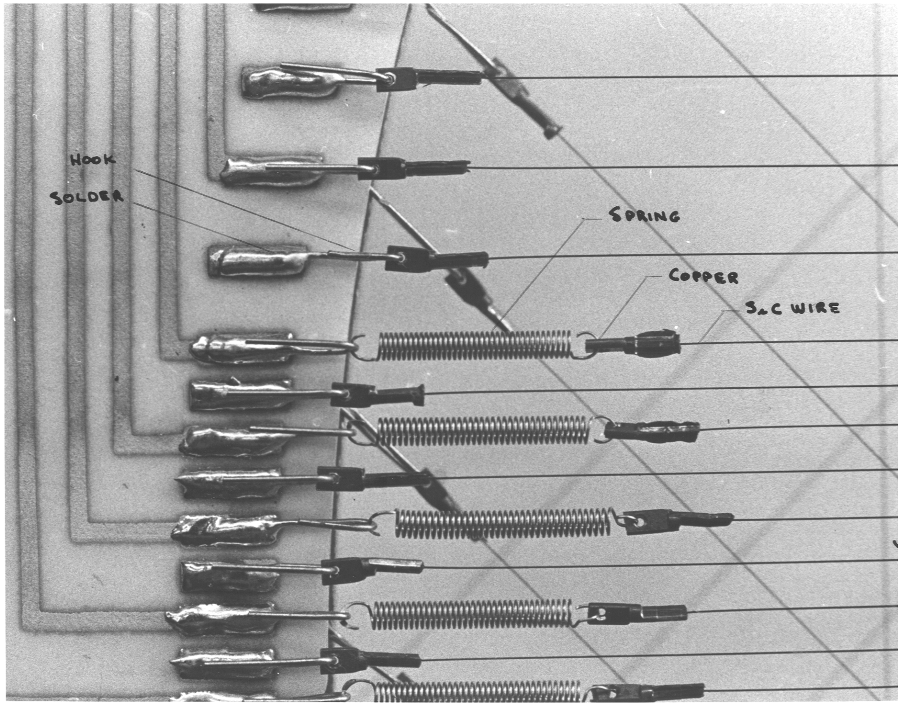
Filament Properties	
• Diameter	— 5.6 MILS — 140 μm^2
• Tensile Strength	— 500 + Ksi — 350 + Kg/mm^2
• Modulus	— 62 Msi — 43 Kg/mm$^2 10^{-3}$
• Density	— .12 Lb/IN^3 — 3.3 g/c.c.



Low Cost Carbon Monofilament Substrate

Wire attachment methods

- For the 0.1 mm SiC wires, we crimp copper sleeves on the ends, attach a spring on one end, and string the wire between hooks. We use springs on our wires to keep tension on them to avoid sagging due to thermal expansion. (33 cm harps in Area A, 1L harp, WSs.)
- 0.032 mm C wires are electroplated with Cu at ends and then soldered onto harp card.
- 0.032 mm C wires are too fragile to use spring arrangement.



Width error vs. number of harp wires

- Model of errors in width measurement due to number of harp wires.
- Only need wire spacing to be less than 1 rms to get accurate fit to a Gaussian profile.

error = abs[(true width) – (fitted width)] + (error in fit width)

40,000 particle PARMILA model of SNS at 7.5 MeV at D-plate wire scanner.
rms width = 0.180 cm.

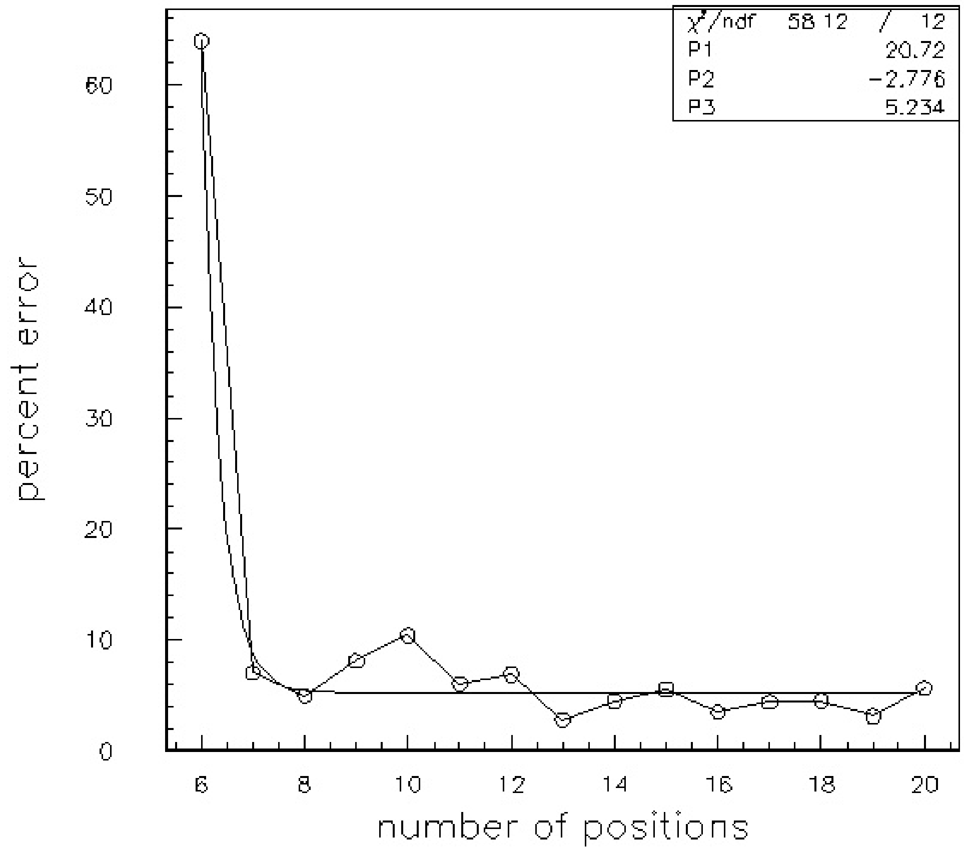
Absolute error = 2% of max.

Relative error = 1%

Gaussian fit to data.

Wires are equally spaced across 2 cm.

12 positions corresponds to 1 sample per rms beam size.

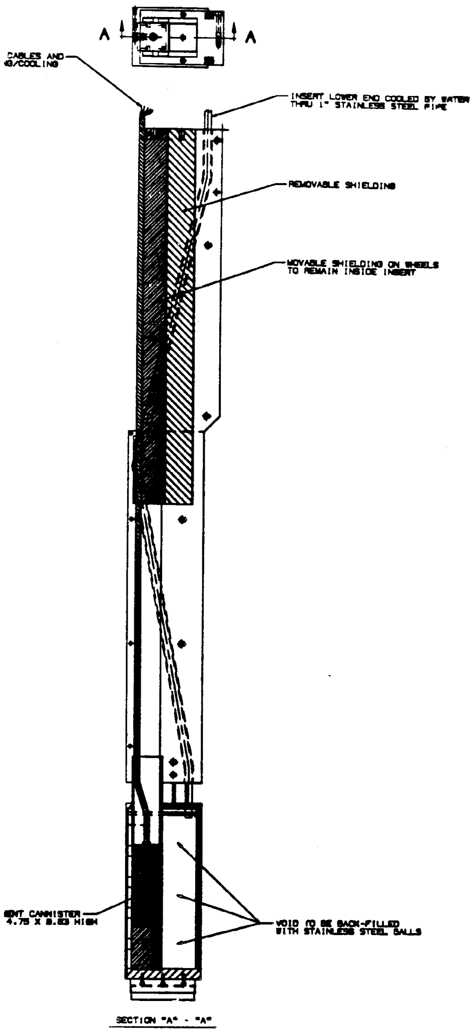


Transporting the signals from the detector

- We use Kapton cables to get signals out of high radiation areas.
- We once used MI cable, but Kapton has been in use now since the mid 1980's with no problems.
- Use angled channels for the cables so there is no line of sight to the radiation source.
- Noise pick up has been a problem. Recommend putting signal cables in conduit, and using shielded twisted pair cables and differential-input electronics. This has worked well for the LANSCE harp.

Cable channels

- Example of A6 harp in Area A.
- Cable channel has angles to avoid line-of-sight to radiation source.
- Channel size should also be minimized since low-energy neutrons flow up the channel like a gas.



Harp vacuum environment

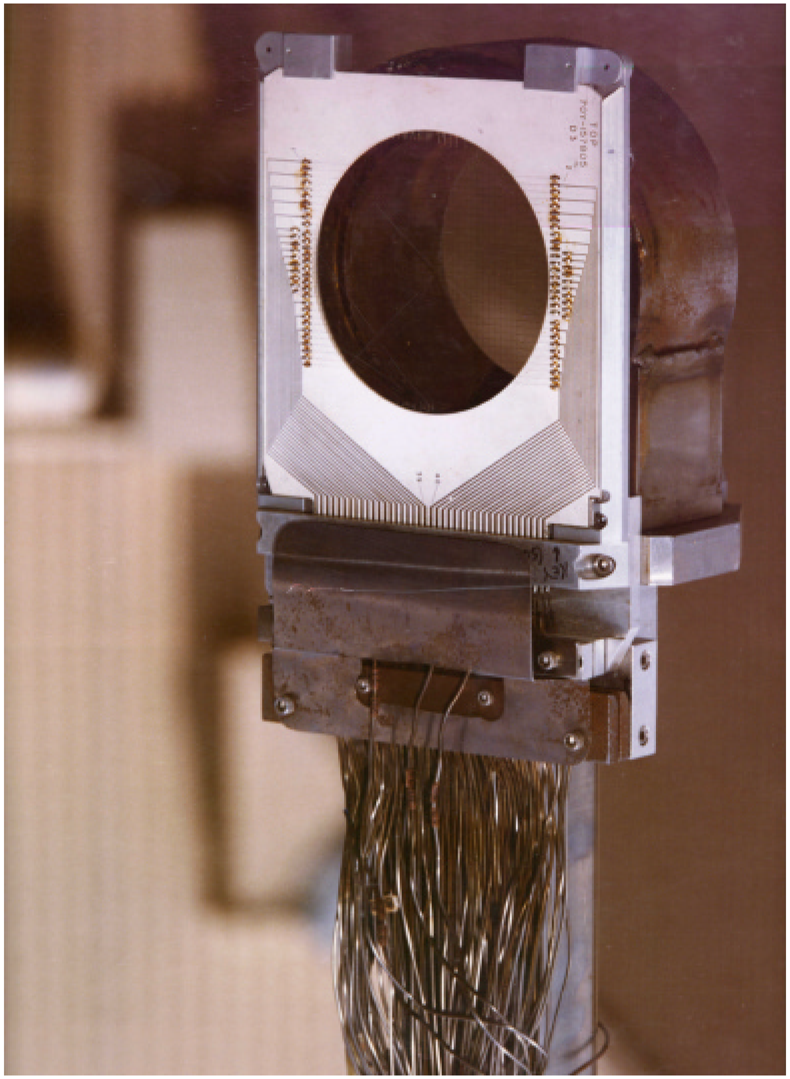
- At LANSCE we have operated harps in pressures as high as 10^{-3} Torr, but 10^{-5} or 10^{-6} Torr would be better.

Back scatter from vacuum window and target

- The LANSCE target harp is located just 17 cm upstream of the vacuum window and 85 cm upstream of the target.
- We were concerned about backscatter from the target and the window affecting the profile measurement, especially due to back scattered particles passing through the PC board traces, the springs, and the hooks, all of which have much more cross section than the harp wires.
- We put a 5 cm thick tungsten collimator between the window and the harp, which has worked very well.

Lessons learned

- This is an example of an old 10-cm insertable harp for Area A.
- Very radioactive due to current monitor attached to same assembly as harp. New harp assemblies no longer have current monitors attached, and detector-end of frame is made of aluminum.
- MI cables difficult to work with. We now use Kapton cables.
- Even new assembly is 16 rem/h after two-month cool down for 1AHP02.



Possible harp improvements

- Stagger signal wires so that if one breaks and falls against the others it will not short them all out.
- Better self test capability.
  - At LANSCE we pulse HV plane and look for capacitive pick up on signal wires.
  - Consider bringing both ends of each signal wire out to a connector for continuity and other tests. *Drawback: double the number of signal cables.*
  - Consider resistors or capacitors mounted on harp to couple test signal on to signal wires. *Drawback: radiation damage to the resistors and capacitors.*
  - Any other ideas?

LANSCE vs. SNS

	LANSCE	SNS
Harp size	10 to 33 cm	28 cm
Average beam density	0.07 to 160 $\mu A/mm^2$	0.26 $\mu A/mm^2$
Peak beam density	6 to 14,000 $\mu A/mm^2$	6,300 $\mu A/mm^2$
Fixed vs. insertable	Both	??
Proximity to tgt.	A6: 50 cm to window, 100 cm to target. PSR: 17 cm to window, 85 cm to target.	a few meters
Number of signal planes	2	3

SNS harp lifetime estimate

- Estimate of SNS harp lifetime based on LANSCE harp lifetimes

	σ_x (mm)	σ_y (mm)	Timing	Avg. current density (μA/mm^2)	Peak current density (μA/mm^2)	Lifetime
A6 harp	16	16	1 mA, 100 Hz, 1ms pulses	0.62	6.2	1 year
Lujan TGT harp	15	15	100 μA, 20 Hz, 250 ns pulses	0.071	14,000	2 - 7 months
SNS TGT harp	50	17	1.4 mA, 60 Hz, 695 ns pulses	0.26	6,300	**8 months ????**

Summary

- Rad-hard construction techniques:
  - Ceramic PC boards.
  - Platinum traces & lead free solder to avoid mixed waste issues.
  - Kapton cables in angled channels.
  - Only materials used are ceramic, metal, and Kapton.
  - Aluminum frames and support structures.
- At LANSCE we've had good luck with 0.032-mm C and 0.10-mm SiC wires.
- SNS target harp lies in the middle of the parameter space (beam density, proximity to target, size) of existing harps at LANSCE.
- Fabrication should not be a problem, but lifetime will likely be a problem.